SPECIAL STUDY
BICOLOR EVALUATION REPORT
SUPPLEMENT TO
PHOTOGRAPHIC EVALUATION REPORT
MISSION 1103

FEBRUARY 1970

NATIONAL PHOTOGRAPHIC INTERPRETATION CENTER

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SPECIAL STUDY: BICOLOR EVALUATION REPORT

SUPPLEMENT TO PHOTOGRAPHIC EVALUATION REPORT MISSION 1103

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Production and distribution of the attached report has been intemperately delayed by higher priority intelligence community requirements. The conclusions and recommendations were made known to the community through other channels several months ago. This report is intended primarily as a documentation of the bicolor study. The NPIC regrets any inconvenience caused by this delay.

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PURPOSE

This report summarizes the investigations conducted to evaluate bispectral-bicolor photography as it pertains to the KH-4B Camera System. Included are discussions of the origins of the technique, difficulties encountered during the investigation, and the apparent position of the technique relative to other photographic intelligence acquisition techniques.

It should be noted that the conclusions of this report are stated under the headings of General and Technical. Those under the General heading pertain to the overall field of color photography and specifically bicolor, whereas the Technical section covers specific conclusions of the report oriented toward the interests of the researcher-technician.

ABSTRACT

Bicolor photography from satellite altitudes is being investigated as a possible intelligence collection technique. This study is based on the collection of bicolor photography as accomplished using the KH-4B photo reconnaissance system. The technique makes use of red and green filtered black and white imagery that can be color reconstituted without affecting the conventional exploitation procedures of the black and white records.

The results of the test indicate that some target colors can be detected, provided the objects are large enough to be resolved throughout the process of image reconstruction and their color is conspicuously different from surrounding objects. The bicolor process does not provide the color fidelity of conventional color materials and requires significantly more time for reproduction. The bicolor photography acquisition technique caused relatively little degradation to the original camera record, whereas a significant loss in spatial resolution occurs with currently available tripack color materials (June 1969).

The relatively small scale of the KH-4B imagery and its panoramic, convergent stereo geometric distortions have severely limited the ability of the process to provide imagery comparable to the potential demonstrated through bicolor experiments conducted with framing cameras.

As with previous attempts to evaluate the performance of color acquisition techniques, the lack of specifically oriented color interpretation keys has hampered attempts to determine the capability of such a system to support the intelligence community.

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PREFACE

An investigation of the use of the bicolor photographic technique in KH-4B satellites was undertaken as part of NPIC's continuing effort to improve the intelligence community's ability to derive intelligence information from reconnaissance photography. To coordinate the investigation, a Bicolor Evaluation Committee was formed with representatives from both the photo science and photo interpretation disciplines.

This report presents the results of a comprehensive study of the technique used in providing bicolor photography and the potential of that technique to support the photo interpretation effort at the National Photographic Interpretation Center.

I. CONCEPT

A. Color Photography Development

Since the first experiments to develop the process of photography, attempts have been made to record more than the brightness values of the original scene. This additional information is color, an object's property of selectively reflecting or absorbing wavelengths of light.

The first successful attempts to produce color images were shown at the Royal Institute of London in 1861 by James Clark Maxwell. His demonstration revealed a process that consisted of photographing red, green, and blue absorption or reflection records; printing these records to a positive image; and then projecting these images through their respective taking filters. This process was very successful, and the same technique is used today for fine quality color photography. The principles of the process are the basis for the production of dye transfer color prints, technicolor motion picture release prints, and even color television images.

Conventional color films such as Ektachrome and Kodachrome also use the three-color record theory. However, instead of three separate records, all three records are recorded in a single multi-layered piece of photographic film called a tripack in which a set of dyes selectively absorb red, green, and blue light.

The bicolor process is an outgrowth of Maxwell's first experiments. After his demonstration various individuals experimented with techniques to place the three records on a single support, but limited technology prevented their success. However two glass plates could each be coated with a different emulsion/filter combination of specific sensitivity, sandwiched together, exposed simultaneously, and each developed and dyed separately. The two records were then laminated together in register to create a "color" transparency. This two-color process or bicolor was demonstrated by Dr. C. E. Kenneth Mees of the Eastman Kodak Company in November of 1915 at the Memorial Art Gallery of the University of Rochester, Rochester, New York. This process and several other two-color techniques are discussed in 1914 through 1919 issues of the British Journal of Photography. The two-color Kodachrome process was used by the Eastman Kodak Company for color portraiture until the first tripack Kodachrome became available in 1936.

B. Bicolor Process Development in the National Reconnaissance Program

In June 1966 the camera contractor suggested that the bicolor technique be investigated for possible use in the KH-4B camera system, which was then under development. A group of studies, the [redacted] investigated several proposals for the KH-4B. [redacted] panoramic camera system mounted in a U-2C aircraft was employed in the bicolor tests because it provided a convenient testing configuration, while taking advantage of the similarity of the [redacted] and KH-4 camera designs. The following are the conclusions of the Bicolor [redacted] Report* which recommended bicolor be tested in an orbiting camera system. 25X1A 25X1A 25X1A 25X1A

"Conclusions: This test enables several conclusions to be made that relate to the KH-4B system. It should be noted, though, that because of the differences in scale, it is expected that much better results will be obtained from the KH-4B system than in this test using the [redacted] system. The conclusions follow. 25X1A

1. Color photography is obtainable from this type of panoramic photography using standard black and white film as original negative material. The color is not as accurate as in normal color reversal material due to the two-component nature of the bicolor system. Though reversal color film can produce full color at ground levels, they also are severely limited at high altitudes due to the prevailing atmospheric haze. The fact that bicolor produces limited color is not, therefore, considered a major drawback.

2. Perfect registration will not be possible in the KH-4B system due to the necessity of providing stereo imagery. Neither rectification or orthoprinting eliminates the photographic image of the different sides of the building for each camera. The misregistration is shown by color fringing. This problem will tend to disappear at smaller scales when the ratio of the misregistration to ground resolution is more favorable.

3. The image quality of the original negative produced with the Wratten No. 57 green filter is somewhat less than that of the Wratten No. 25 filter with a second generation [redacted] lens. This difference was not measurable with the MTF/AIM technique, but it was picked up by a subjective analysis. 25X1A

4. The effect of haze can be more easily controlled in bicolor photography than with reversal color film by processing each of the records to its optimum gamma. In addition, the contrast loss due to atmospheric haze is much less, since a green filter is used rather than a blue sensitive record as in standard reversal color film.

*TCS-14172/67, Bicolor Evaluation, [redacted] Report No. 16 [redacted] FLIGHT No. 2), 15 September 67 TOP SECRET/No Foreign Dissem 25X1A

5. A bicolor test is recommended on a KH-4B engineering flight."

25X1A

In subsequent [redacted] briefings the contractor and operations personnel explained their confidence in the [redacted] conclusions and their proposal for implementing the [redacted] recommendation. Included in their discussions were the following points relevant to color photography in the KH-4B camera system.* 25X1A

1. Bicolor acquisitions can be programmed on a near real-time basis by a ground commanded filter change.
2. Spatial resolution loss on bicolor photography is less than on conventional color imagery.
3. Since currently available color films have relatively poor spatial resolution, target coverage must be more selective than with bicolor acquisitions.
4. The use of color emulsions necessitates a nearly impossible prediction of a target's position in the mission film load so that film can be spliced into the payload at the proper place.

* Ibid.

II. DESCRIPTION OF THE BICOLOR TECHNIQUE

A. Bicolor Image Generation

To comprehend the technique of bicolor image production from film acquired by the KH-4B camera, it is convenient to first consider the basic techniques of color separation photography using conventional framing cameras, then apply these processes to the KH-4B products.

As previously discussed, full color photographic reconstruction of an original scene was first achieved by generating three color separation or spectral records. Until a single shot camera was developed, the photographer was limited to a studio where precise control of the scene and its environment could be accomplished. The photographer had to make three successive photographs, each through a separate filter (red, green, and blue), while maintaining a fixed position for the camera and scene to permit future registration of the three records. As the technique was refined, a camera using a series of beam splitters was developed. It allowed a single exposure to image on three pieces of photographic film simultaneously. After the film was exposed, each was developed conventionally.

For viewing these spectral records as color images, registered projection and color printing were used. For projection, each negative was printed to a film positive and projected in register onto a common surface through the appropriate taking filter. Color prints were made by the dye transfer color printing technique. The negatives were used to print dyes of a complementary color (cyan to absorb red light, magenta to absorb green light, and yellow to absorb blue light) in register onto a common paper surface. Today high quality color reproductions are still achieved by these techniques of color separation and reconstruction.

To produce a bicolor print, the red and green positive records are projected conventionally and the blue record is omitted. The scene has an overall yellow color, but blue light can be used to create a more pleasing and realistic color image. This blue can be either a uniform field of blue light, or the red and green images can be used as a mask to add the blue light proportionally. The resulting image can either be viewed directly or photographed onto conventional tripack color materials. Paper prints can be produced by printing the negative red and green images through complementary filters and adding yellow light (the complement of blue) to the image.

When compared to a full color image, the final bicolor images produced by these techniques differ to some degree. All red and green objects of the original scene appear red or green respectively in the bicolor image; however, blue objects will appear as a shade of green. Additionally, some subtle colors will be impossible to detect. It should also be noted that printing stereoscopic records into bicolor destroys their depth characteristics, although black and white prints can still be used for stereoscopy.

B. KH-4B Application

Since the KH-4B camera system is a panoramic, convergent stereo system, image manipulation is necessary to provide images that can be registered and printed into bicolor.

Rectification of the panoramic image can be accomplished by a device similar to a panoramic camera that re-images or prints the original negative, while removing the distortion that the original contains due to the initial acquisition technique. The rectification device used for these experiments was the Gamma I Rectifier.

The geometric distortions that result from changing the camera's viewpoint can be removed by a process called orthoprinting. This process re-images each point of the photographic record to a point in space that corresponds to the original scene and projects the corresponding density to a new position on another piece of film.

To produce KH-4B imagery suitable for bicolor printing, the original negative is first rectified to remove panoramic distortions, then orthoprinted to permit registration. This produces a negative two generations removed from the original. These images can then be printed to either a color transparency or a color paper print.

The conclusions of this evaluation of bicolor photography are based on rectification and orthoprinting as accomplished by the Aeronautical Chart and Information Center (ACIC) using the Gamma I Rectifier, the AS-11C and the Gegis-Zeiss orthophoto devices.

III. STUDY OF IMAGERY

A. Mission 1102 Bicolor Experiment

The initial tests of bispectral acquisition techniques occurred on Mission 1102 (December 1967) when one operational pass [redacted] were collected in the bispectral mode. To view this material NPIC acquired the Automatic Registering Electronic Stereoscope (ARES) with a bicolor viewing attachment, since some distortion correction of the images is necessary for even a low resolution examination. This device electronically images two records in register through the use of a beam splitter and cathode ray tubes (CRT). Each CRT image is intercepted and appropriately filtered to effect a bicolor image. The ARES provided a potential for a preliminary examination of the collected imagery and a selection of targets for further study. The relatively low resolution of the device (due to the original design specifications) was somewhat overcome by the production of film positive enlargements before viewing on the ARES.

25X1A

25X1A

Extensive use of the ARES showed that it provided a near real-time technique for reconstitution of bicolor imagery. It was, however, inadequate for detailed target analysis because the image resolution was badly degraded by the electronic imaging process and the colors presented were a function of the electronic signal distortion as well as the image density variations.

ACIC later delivered a sample of orthoprints generated on their Automatic System No IIC electronic rectifier from which bicolor reproductions were made. While the results provided better resolution and more constant color values than were obtained from the ARES, the color saturation, color fringing, and resolution were far from acceptable for photo interpretation.

An attempt was also made to interpret spectral differences by visual comparison of the variations in gray tones between the green and red records. It was concluded that at the KH-4B scale spectral differences can most successfully be identified by the human eye when they are presented in color.

An evaluation of the black and white photographic quality of the red versus the green filtered imagery*was conducted concurrently with the above investigations. The conclusions follow.

1. The contrast range is significantly reduced when the SFO-5 (green filter) is used in place of the Wratten 21 (red filter) or the Wratten 25 (red filter).
2. Apparent image sharpness is poorer by a noticeable degree on the SFO-5 photography compared to the Wratten 21 and Wratten 25.
3. The only suitable resolution target display imaged during the bi-spectral acquisition indicates a significant difference (approximately 2½ feet) in ground resolution between SFO-5 photography compared to that of the Wratten 25.
4. The effect of image quality degradation caused by the use of the SFO-5 filter is minimized when the photography is viewed in (black and white) stereo with the higher quality, higher resolution photography exposed through the Wratten 25.
5. The overall image quality of the green filtered record is comparable to that of a normal KH-4A mission.

B. Domestic Tests

The investigations of the bicolor process indicated that more data were necessary to determine the capability of bispectral imagery to detect target differences. A series of ground truth exercises using ground based and correlatable aerial views increased knowledge of bicolor's capability to provide meaningful data. In these tests, A-2 framing cameras were mounted side by side and the photos were taken simultaneously, thereby eliminating the rectification problem and making very clear bicolor reproduction possible, using the pin register system for printing. A third camera took conventional color photographs which permitted a comparison of color values between the two products (see Figures 1 and 2).

These tests showed that some colors were faithfully reproduced by the bicolor process and could potentially provide information of intelligence significance over and above that provided by black and white photography. In some cases, an exaggerated saturation of colors as provided by the bicolor (but not the conventional color film) proves to be a distinct advantage. It is understood, however, that special printing of tripack color films would have a similar result. As a rule, the yellow tones are very difficult to detect on normal color film and impossible to distinguish on bicolor. This is not the case with the brown tones,

*NPIC Cable 3133, 28 February 1968 TOP SECRET RUFF (Complete text is given in Appendix B, page 20.)

which show up well on both systems. However, it is somewhat difficult to distinguish a brown color from a dark or "contaminated" red.

An investigation of the application of the bicolor technique to analysis of the uranium ore concentration industry was undertaken. Ground truth data as well as aerial imagery consisting of red and green filtered black and white records (bicolor), SO-121 (conventional color), and SO-180 (camouflage detection color) of specific uranium ore concentration facilities was acquired. This material permitted investigation of the various techniques with respect to their ability to detect specific target signatures.

Relatively little difficulty was encountered with exploitation of the aircraft-acquired bispectral acquisitions, since framing cameras were used and the imagery could be printed directly into bicolor without rectification and orthoprinting.

The quality of the resulting bicolor prints was superior to any operationally acquired bicolor material and provided significant data to support operational target analysis. For example, stains could be distinguished on the roofs of buildings where uranium oxide was handled. This suggests that a system where two cameras are vertically mounted could produce usable results, but a covergent stereo system presents very great image displacement problems.

C. Mission 1103 Bicolor Experiment

The first successful bispectral acquisition of specific intelligence targets was accomplished on Mission 1103 (launched 1 May 1968). Because of the need for interagency cooperation in the exploitation of this and all future bicolor photography, and to insure a coordinated, meaningful evaluation of the bispectral technique, the Bicolor Photography Evaluation Committee was established on 14 June 1968. The committee included membership of NPIC and CIA intelligence analysts, photo interpreters, and photo scientists.

As a first order of business the committee convened a communitywide meeting to discuss possible bicolor reconstitution techniques. The relative quality and the production problems of each available technique were agreed to be the most important considerations in the establishment of a usable method for production and exploitation.

Since a number of instruments were available for the rectification and/or orthoprinting process*, a small-scale test was first necessary to decide which equipment was most appropriate for use in the evaluation of bicolor as an intelligence gathering technique. Toward that end NPIC submitted two target areas to be processed by each available method. Both the U.S. Army Topographic Command (TOPOCOM) and ACIC had equipment available for possible support to the project, and each was supplied with prints to its specifications. The results of that test would then dictate which rectification, orthoprinting, and color printing techniques** would be employed on a larger scale test designed to indicate the intelligence value of the bicolor technique in the KH-4B camera system.

The printing techniques decided upon were those previously described using the Gamma I Rectifier and the Gegis-Zeiss Orthophoto Printer.

Twenty-one target complexes were selected on the basis of their having been covered in the bispectral mode and because of their color-oriented intelligence potential. These covered the gamut of target types imaged under varying weather conditions and having variable photographic quality.

An analysis of the 21 intelligence targets as processed and printed by the previously mentioned techniques can be found in Appendix C.

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* Among those available were the Unimace, AS-11C, Gegis-Zeiss Orthophoto Printer, and the Gamma I Rectifier.

** The two color printing methods available were the pin register technique using color tripack material and the 3-M electro-color process (at the Air Force Special Projects Production Laboratory, Westover Air Force Base).

IV. IMAGERY EXPLOITATION

A. Image Processing

The effort required to produce the necessary imagery for interpretation is a significant factor to consider in the evaluation of the bicolor process. Aside from the necessary routing of materials, three distinct major tasks are necessary to exploit the bispectral imagery: plotting printing, and correlation.

In order to provide the analytical data for the orthoprinting process, each pair of stereo frames had to be contour plotted using the Analytical Stereo Plotter #11C (AS-11C). The resulting data served as input to the Gegis-Zeiss Ortho-Printer (GZ-1) to produce the red and green orthophotos. This process, undertaken by ACIC, required 3,209 man-hours for the production of the materials to produce the 21 bicolor images for this test.

The second major effort involved the trial and error techniques necessary for color reconstitution of the separation orthoprints. Since each pair of orthophotos has been acquired and processed separately, each had to be printed using different processing parameters.

Finally, after the imagery had been produced, a technique of correlating the bicolor print colors to possible ground or target colors had to be developed. When conventional color techniques are used, the photo interpreter can more easily relate target colors to colors of objects while he views the imagery. With bicolor imagery only a red-blue (warm-cold) type of color discrimination is possible. Hence, the interpretation process is different.

B. Image Value Assessment

A cursory examination of the potential of information content for bicolor imagery indicates that two different records (sensed in different parts of the electromagnetic spectrum) of a single object are better than two quite similar ones. However, the following topics need to be investigated to establish analytically the validity of such an assumption.

Do the records differ significantly?

Are these differences verified or supported by collateral information?

Are existing spectral differences lost through a lack of sensitivity (both chromatic and spatial)?

Are detected differences of significance to the intelligence community?

1. Record Density Differences. The easiest question to answer relative to bicolor photography from the KH-4B is that of the differences in image quality between the two records. As previously reported in the black and white evaluation of the bispectral imagery on Mission 1102, the green or SFO-5 record (aft-looking camera) is of lower contrast than the red Wratten 25 (forward-looking camera) record. In addition, it is apparent from an examination of the conjugate imagery of the two records that nonlinear density differences do exist between the records.

2. Significance of Density Differences Between Records. Among the previously mentioned tests performed with Mission 1102, an effort was made to establish the meaning of the differences between the red and green filtered records. The domestic bicolor coverage of Mission 1102 was searched and areas of possible significance were selected. A search of prior tripack coverage (SO-121) of these areas provided a limited quantity of duplicate coverage.

Two striking examples of "color clueing" were apparent: a truck paint factory and the salt reclamation beds in the San Francisco Bay area. An examination of these areas in bicolor indicates that they have significantly different reflectance characteristics than the surrounding areas. A strong red signal was evident on the ARES viewer. Upon checking the SO-121 coverage, these signals were verified. Further investigations of familiar objects such as swimming pools also displayed the expected signatures (stronger on the green record than on the red record).

From this evidence some correlation was established between aircraft high altitude conventional color photography, bicolor photography from satellite altitudes, and known ground color signatures. However, with the bicolor technique it was observed that absolute correlation of imagery to specific target reflectances is impossible. While a specific color can be recorded by the bicolor system, the reverse is not true. Since only two pieces of data are available with bispectral imagery, instead of the three provided by conventional color photography, a bicolor signature represents an entire family of chromatic values. One can predict that a green object on the ground will reproduce a specific hue of green on the bicolor image; however, it does not necessarily follow that a green object in the bicolor print is actually green on the ground--it could also be some hue of blue. Color distortions due to changing atmospheric conditions between forward and aft acquisitions are also a factor in bicolor analysis.

In an effort to determine what possible information could be gained from bicolor versus conventional black and white imagery, the following specific experiment was conducted with Mission 1102 bicolor imagery. A group of photo interpreters was given imagery of a housing development [redacted] and asked to note differences between the roofs of the houses. Each group was given the task twice. All completed the first attempt using only the black and white records; on the second attempt half of the group saw a bicolor presentation on the ARES viewer. The bicolor presentation produced a significantly higher number of difference detections than the examination of black and white film positive records. However, no clear evidence of agreement as to a specific signature for a specific target was apparent, perhaps due to the extreme variability of the viewing device.

25X1A

This test contributed to the conclusion that bispectral analysis on KH-4B photography is most successful when the tonal differences are displayed in color (bicolor).

3. Bicolor System Limitations. It is obvious that bispectral photography from a satellite cannot record all of the spectral reflectance differences that exist in an original scene. The problems of spatial resolution, the compression of tones due to system parameters (both acquisition and reproduction), and the limited information capacity of only two different records make it impossible for such a technique to gather the same amount of information as the human eye, or even tricolor package. In most cases, however, a complete spectral signature (from ultra-violet through the visible to the long infrared wavelengths) is not necessary for target identification. Some targets present a unique bicolor signature that could be used for identification.

The major detriment to a conclusive assessment of the value of bicolor (or any other color presentation) is a lack of knowledge as to what color keys exist for specific intelligence targets. This data is not available because little color coverage has been acquired over denied areas. Without this coverage, it is not possible to correlate colors to targets and develop appropriate color keys.

As stated throughout this report, the potential and the limitations of the bicolor technique are generally recognized. The hue, saturation, object to background relationship, color integrity and resolution required to answer a specific intelligence requirement must be weighed against the potential of the bicolor system.

4. Significance of Detectable Density Differences. The spectral characteristics of some targets can be detected by the use of the bicolor technique. A photo interpretation report correlated the colors produced by a bicolor presentation of that target with the commonly accepted activity of the installation. Bicolor can provide additional information to the intelligence community, although none of the information derived from this test altered any intelligence analysis.

D. Factors Affecting Interpretability

Bicolor imagery and conventional color photography today are of poorer spatial resolution than black and white imagery. Additionally, little is known of the tone reproduction characteristics of bicolor imagery and less is known about the psychological effects of color imagery related to object recognition. Therefore, any investigation of the suitability of bicolor imagery for photo interpretation is somewhat limited.

A previous study (see Appendix B, page 20) has examined the photo interpretability of the black and white (forward and aft) photography acquired bispectrally when interpreted conventionally. This analysis indicated image degradation occurred when the green filter was used and, under optimum conditions, was comparable in magnitude to the difference between KH-4A and KH-4B images. When used in the stereo mode, the degradation was minimized.

The following subjective generalizations are possible relative to the factors that affect the quality of bicolor images.

The most significant factors affecting the quality of a bicolor image are clouds and haze, which change the amount of their reflectance and scattering of light differently when frames are exposed from different look-angles, as with the KH-4B convergent stereo system. Manifestations of these atmospheric changes are loss of conjugate imagery, in severe cases, or distortion of the bicolor obtained, in less severe instances. These color changes or shifts occur because the colors in a bicolor print are a function of the black and white densities of the forward and aft original negatives.

The second major factor affecting image quality is that of image relief. The orthoprinting process (which causes some loss of spatial and tonal resolution) can, within limits, return all image points to a common plane; however, the extreme elevation differences of mountainous terrain cannot be accommodated. This problem is compounded by the difference in look-angles of the two cameras. These produce two images with different views of the same object--the top and left side of a building appear in one photograph and the top and right side in the other. When one attempts to register this imagery into a bicolor print, all such objects have red and green fringes.

An estimate of the spatial resolution of a bicolor print made from KH-4B photography using current techniques of reproduction is approximately 30 feet. However, since so many factors affect such an estimate, the figure is of questionable integrity without a specific analysis of each target under consideration.

No practical technique for a determination of the operational spectral sensitivity of bicolor is currently available. That is, we cannot determine the ability of the technique to distinguish between objects of similar colors or what difference between two objects is necessary for detection (with the data base that can practically be collected). Any such determination would have to be done on a purely theoretical basis.

V. CONCLUSIONS

The conclusions of this report are listed under the headings of "General" and "Technical." Those in the "General" category pertain to the overall subject of bicolor photography and its interpretation. Those listed under the heading of "Technical" are technically oriented and, in some instances, are additional findings of the study that pertain to the exploitation and assessment of bicolor photography as conducted during this study.

A. General

1. Color imagery can be reconstructed from bispectral imagery collected by the KH-4B satellites.

   a. The fidelity of color so reconstructed cannot currently be positively controlled and is subject to significant variations. The resulting color, however, is generally correlatable to known color differences.

   b. The process of image rectification, registration, and printing required by current processing procedures reduces the resolution of the resulting images from the [redacted] obtained in black and white under optimum conditions to 25-30 feet in the reconstructed color. 25X1D

   c. The new intelligence information derived from the spectral differences of the two records has not changed any previously completed intelligence analysis over the limited target sample provided.

2. The image quality recorded through the green filter is noticeably poorer and is more adversely affected by degrading atmospherics than the red filtered imagery. The difference in resolution between the two images is approximately [redacted] under optimum conditions, and is comparable to the difference between normal KH-4A and KH-4B images.

25X1D

3. Bicolor acquisition can be programmed on orbit, providing a capability of obtaining spectral information intermittently during the mission in accordance with the opportunities and dynamics of the mission. Use of conventional color film for coverage of selected targets requires calculation of the position of the target acquisitions in the total load and splicing color film into the payload at the proper places.

4. The cost and time involved in the current procedures of image rectification, contour plotting, and color printing are excessive and preclude the use of bicolor techniques on a mass production, rapid response basis.

5. Reconstructed bicolor images, using currently available technology, have less resolution and poorer color fidelity than conventional tripack color photography. The black and white stereo images resulting from bispectral acquisition, however, have greater resolution than conventional tripack color film (June, 1969).

B. Technical

1. The best state-of-the-art technique of bicolor production is accomplished as follows:

a. Image rectification - Gamma I Rectifier
b. Contour plotting - AS-11C
c. Color printing - a pin register board; on tripack color transparency material

Alternate techniques considered were contour plotting and orthophoto printing through the use of the Unimace; simple rectification; superimposition of the positive image without distortion removal; and the use of the Automatic Registering Electronic Stereoscope.

2. Bicolor has been demonstrated as a suitable technique for determining the general hue of an object (warm or cold) within certain limitations (atmospherics, object size, etc.). However, it is not practical, with current technology, to predict the potential of bicolor to provide the photo interpreter with information as to the precise hue of an object. That is, red-green discrimination is readily available through bicolor; however, green to blue or red to orange discrimination is questionable. Since the degree of atmospheric attenuation is a necessary consideration in determining object hue, saturation, and brightness from a bicolor image, it may never be possible to determine this type of information with a two-color system.

3. The bicolor technique used experimentally in support of this evaluation employing framing cameras (A-2 camera system), produced imagery that contains significantly more tonal information than do the KH-4B panoramic bicolor acquisitions. Reasons for such results are attributed to the differences in spatial resolution between the two systems, the loss of tonal values due to orthoprinting techniques,

and the lack of precise registration of the panoramic camera photography that is associated with the look-angle differences between forward and aft images.

4. As stated throughout this report, the potential and the limitations of the bicolor technique are recognized. The hue, saturation, size, object-to-background relationship, and color integrity required to answer a specific intelligence requirement must be known to completely evaluate any color reconnaissance technique. Without specific values for these criteria it is impossible to give an explicit reply to the question, "What is the value of bicolor photography?"

VI. RECOMMENDATIONS

A. Pending further development of bicolor reconstruction techniques, conventional tripack color film should be used to satisfy color-oriented intelligence requirements with the KH-4B system unless the requirement for color coverage is limited to a very small number of targets which, due to operational constraints, cannot be satisfied by splicing tripack color film into the payload.

B. Further investment in the improvement of bicolor technology of processing procedures should be dependent upon an assessment of the cost effectiveness of the potential bicolor technology in comparison to tricolor technology. No additional experimentation with the bicolor technology should be conducted pending completion of such a feasibility study.

C. Color keys that relate to specific intelligence requirements should be developed to aid both the photo interpreter with his interpretation tasks and the photo scientist with his task of system development and evaluation.

FIGURE 1

This Aerial Ektrachrome (SO-121) photography is representative of the types of targets covered with simultaneous SO-121 and bicolor coverage using the A-2 aircraft camera system. This imagery was collected to support the evaluation and interpretation of satellite aquisitions.

FIGURE 2

This bicolor imagery was acquired simultaneously with Figure 1, using a group of three vertically mounted framing cameras. The reconstruction was accomplished by supplementing the red and green records with blue light during the printing process to eliminate the overall yellow tone found in prints made from only red and green records. The apparent faithfulness of the bicolor record to the SO-121 image is due to the predominance of objects in the red and green portions of the color spectrum.

25X1D

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FIGURE 3

This 20X enlargement made from the red record original negative illustrates the quality of the forward-looking camera, red filtered imagery of Mission 1103.

FIGURE 4

This photograph is the equivalent of a 20X enlargement from an orthophoto of the original negative used in Figure 3. It is one of two necessary to produce a bicolor print.

25X1D

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FIGURE 5

This 20X enlargement made from the green record original negative illustrates the quality of the aft-looking camera, green filtered imagery on Mission 1103.

FIGURE 6

This photograph is the equivalent of a 20X enlargement from an orthophoto original negative. It is one of two necessary to produce a bicolor print.

25X1D

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FIGURE 7

These three images were produced by photographing the viewing screen (two superimposed cathode ray tube images) of the ARES bicolor viewer. They were created by first enlarging the original negative to black and white film positives, filtering each image (forward and aft) in the bicolor viewer with the appropriately colored filter, and then photographing the resulting image.

FIGURE 8

This is a bicolor print of an operational target acquired on Mission 1103 and described in a photo interpretation report (TCS-20002/69). The printing process used was the same as that used to produce Figure 2. The imagery is representative of the best thus far achieved with the bicolor process and the KH-4B camera system.

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APPENDIX A. LIST OF BISPECTRAL ACQUISITIONS

Mission 1102

Rev	Frames
48	1-61
64	1-16
79	1-49
81	1-20
97	1-27
113	1-36
154	1-47
161	1-28
210	1-40

Mission 1103

Rev	Frames
7	1-92
24	1-202
39	1-129
63	1-23
64	1-31
71	1-90
79	1-22
87	1-144
90	1-102
106	1-146
121	1-102
122	1-108
145	1-26
153	1-72
154	1-161
161	1-16
169	1-94
171	1-191
184	1-36
185	1-81

Mission 1104

Rev	Frames
7	1-65
16	1-16
64	1-44
129	1-26
161	1-17

APPENDIX B. PROCEDURES AND RESULTS OF THE NPIC EVALUATION OF BLACK AND WHITE IMAGERY ACQUIRED IN THE BICOLOR MODE (NPIC CABLE NUMBER 3133, 28 FEB 1969)

A. Subjective Comparison of Wratten Numbers 25, 21, and SF-05 Records

1. Photo-Science Evaluation: To establish a basis for the bispectral image evaluation, the mission material exposed through the primary filters was analyzed. The material selected for analysis had essentially the same acquisition parameters as the bispectral material. Differences in density, contrast and image quality are negligible. The photo interpretation reports indicate similar quality ratings for both records. Assuming no camera malfunctions, subjective and objective results based on this evaluation indicate that any difference in the SF-05 record as compared to the Wratten 21 and Wratten 25 records is the result of the filter. The objective evidence is contained in Part B of this report.

The SF-05 record and conjugate imagery from the Wratten 25 record were visually compared. A compression of density extremes is readily apparent in the green filter record. Due to this compression, low contrast areas show a decided increase in information content on the Wratten 25 material. While in some instances there is more apparent detail in the shadows on the positives made from the SF-05 record, this difference is attributed to the print density dictated by compromise of the D-max and D-min.

The image quality of the Wratten 25 record is superior to the SF-05 for information content. Objects that approach the resolution capability of the system appear much sharper. Apparent edge sharpness of objects viewed at low magnification is generally comparable; however, the Wratten 25 record retains this apparent sharpness much longer as magnification is increased.

2. PI Report: The photo interpreters preferred the Wratten 25 record over the SF-05. Higher contrast and overall sharper imagery were the two major reasons for this preference. They also expressed the opinion that when shadow detail is needed, a lighter print from the Wratten 25 record would be more desirable than the lower contrast of the SF-05 material, which seems to provide more shadow detail on a normal print. Small objects present in the Wratten 25 record can be detected in the SF-05 record; however, identification of these objects is much more difficult. The general conclusions of the photo interpreters is that the majority of the requirements levied for the KH-4B system could

be answered with photography generated in the bicolor mode because the two records complement each other when used in stereo. In addition, the overall information content of the photography exposed through the green filter is comparable to an average KH-4A mission.

B. Objective Analysis

1. Micro-D Traces. To substantiate the results of the subjective analysis, microdensitometric traces of 11 targets were generated. Six targets were selected from the non-bicolor portion of the mission and five targets were chosen from the bicolor portion. Each target was covered stereoscopically and the negative record of each target was traced. The traces were generated by the Mann Micro-Densitometer with an effective slit aperture of 10 microns. Visual comparisons of the traces from the non-bicolor material indicate the similarity that exists between the Wratten 25 and 21 records. However, comparisons of the traces from the bicolor material indicate that a substantial difference in density and contrast exist between the Wratten 25 and SF-05 materials.

The minimum density, maximum density, and the density range of each target has been derived from the traces and is tabulated below. The similarity of the Wratten 25 and 21 records and the non-similarity of the Wratten 25 and SF-05 records is evidenced by the values in the table.

Figure	Pass	Frame	Filter	D-min	D-max	Delta
1	16D	6 Fwd	25	0.72	2.37	1.65
2	16D	12 Aft	21	0.70	2.48	1.78
3	16D	12 Fwd	25	0.75	1.64	0.89
4	16D	18 Aft	21	0.78	1.78	1.00
5	16D	13 Fwd	25	0.65	1.60	0.95
6	16D	20 Aft	21	0.92	1.85	0.93
7	79D	7 Fwd	25	0.45	1.15	0.73
8	79D	13 Aft	SFO-5	0.58	0.93	0.35
9	79D	7 Fwd	25	0.35	0.98	0.63
10	79D	13 Aft	SFO-5	0.42	0.72	0.30
11	97D	12 Fwd	25	0.62	1.27	0.65
12	97D	19 Aft	SFO-5	1.00	1.32	0.32
13	97D	38 Fwd	25	0.36	1.13	0.77
14	97D	44 Aft	SFO-5	0.40	0.88	0.48
15	129D	4 Fwd	25	0.80	2.47	1.67
16	129D	10 Aft	21	0.75	2.47	1.72

Figure	Pass	Frame	Filter	D-min	D-max	Delta
17	129D	27 Fwd	25	0.70	1.65	0.95
18	129D	33 Aft	21	0.75	1.77	1.02
19	129D	32 Fwd	25	0.95	1.57	0.62
20	129D	39 Aft	21	1.20	1.92	0.72
21	154D	4 Fwd	25	0.84	1.92	1.08
22	154D	10 Aft	SFO-5	0.75	1.44	0.69

2. Resolution Targets. Four resolution targets were photographed during the non-bispectral portion of the mission. Seven targets were photographed during the bispectral portion; however, due to weather conditions and/or format location, only one of the targets imaged in the bicolor mode is suitable for this evaluation. The average ground resolution of these targets as determined from the original negative is presented below:

Camera	Pass	[redacted]	Filter
Fwd	16D		25
Aft	16D		21
Fwd	16D		25
Aft	16D		21
Fwd	32D		25
Aft	32D		21
Fwd	129D		25
Aft	129D		21
Fwd	48D		25
Aft	48D		SFO-5

25X1D

As can be determined from the above list, the non-bispectral passes (16D, 32D, and 129D) indicate very little resolution differences between the forward and aft camera records; however, the bispectral material (pass 48D) shows a difference of [redacted] in the IMC direction [redacted] in the scan direction between the forward and aft camera records. This difference, although substantial, represents only one bar group. Also, it should be noted that the [redacted] readings are comparable to a normal KH-4A mission.

25X1D 25X1D 25X1D

C. Summary and Conclusions

1. The contrast range is significantly reduced when the SFO-5 is used in place of the Wratten 21 or the Wratten 25.

2. Apparent image sharpness is reduced by a noticeable degree on the SFO-5 photography compared to the Wratten 21 and Wratten 25.

3. The only suitable resolution target display imaged during the bicolor acquisition indicates a significant difference in ground resolution between the SFO-5 photography compared to that of the Wratten 25.

4. The effect of image quality degradation caused by the use of the SFO-5 filter is minimized when the photography is viewed in stereo with the higher quality, higher resolution photography exposed through the Wratten 25.

5. The resolution of the green filtered record is generally comparable to that of a normal KH-4A mission.

25X2

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